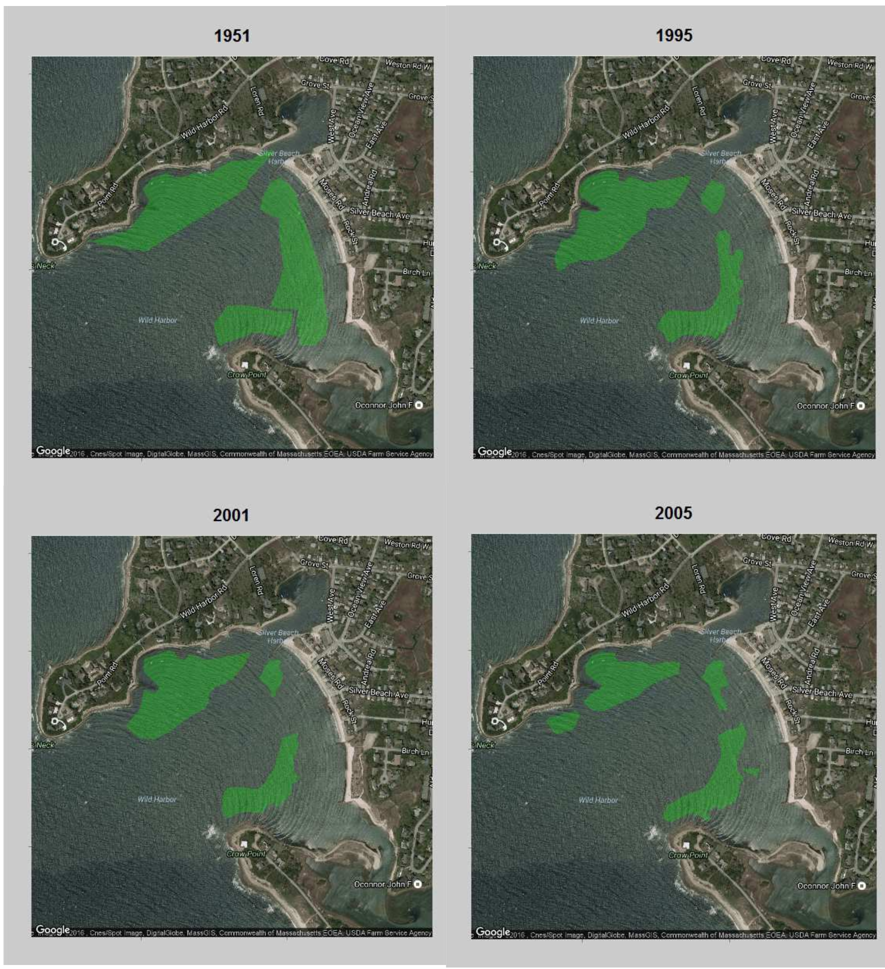
Draft
Wild Harbor Estuarine System
Total Maximum Daily Load
For Total Nitrogen
(CN #397.0)



Wild Harbor Eelgrass Coverage Over Time

COMMONWEALTH OF MASSACHUSETTS
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August 2017

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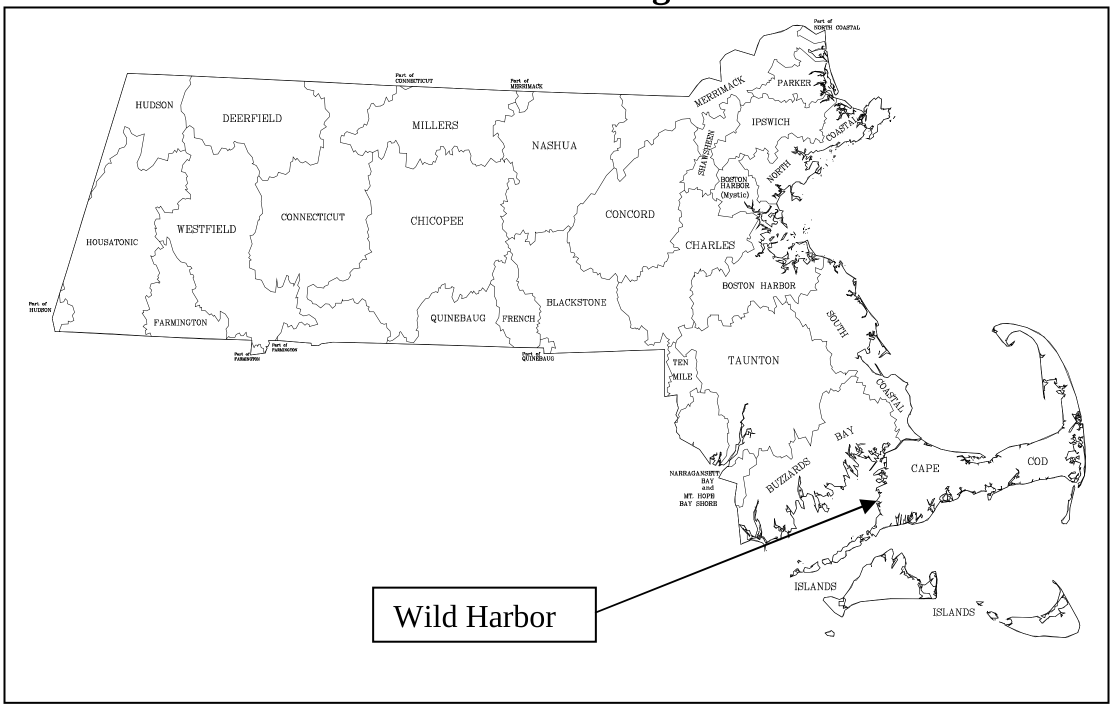


Key Feature: Total Nitrogen TMDL for Wild Harbor System

Location: EPA Region 1**,** Towns of Falmouth, Bourne and Sandwich, MA

Land Type: New England Coastal

303d Listing: Wild Harbor (MA95-20) has a TMDL for Fecal Coliform (Category 4a, 2014 Integrated Report), but was found to be impaired for nutrients during the MEP study. Wild Harbor will be evaluated for nutrient impairment in a future listing. Wild Harbor River (MA95-68) has a TMDL for Fecal Coliform (Category 4a). Wild Harbor River is listed (Category 5) for Nutrient/Eutrophication Biological Indicators, although it was determined to be meeting Aquatic Life Use during the course of the MEP study. Wild Harbor River and Dam Pond Stream, (no assessment unit ID) are hydraulically connected to Wild Harbor and therefore have been assigned Protective TMDLs.

Data Sources: University of Massachusetts – Dartmouth/School for Marine Science and Technology; US Geological Survey; Applied Coastal Research and Engineering, Inc.; Cape Cod Commission; Town of Falmouth

Data Mechanism: Massachusetts Surface Water Quality Standards, Ambient Data and Linked Watershed Model

Monitoring Plan: Cape Cod Commission/Town of Falmouth – Buzzards Bay Coalition's Baywatchers Monitoring Program with technical assistance by SMAST

Control Measures: Sewering, Storm Water Management, Fertilizer Use By-laws

Executive Summary

Problem Statement

Excessive nitrogen (N) originating from a variety of sources has added to the impairment of the environmental quality of Wild Harbor. In general, excessive N in these waters is indicated by:

- Loss of eelgrass beds, which are critical habitats for macroinvertebrates and fish;
- Undesirable increases in macro-algae, which are much less beneficial than eelgrass;
- Periodic decreases in dissolved oxygen concentrations that threaten aquatic life;
- Reductions in the diversity of benthic animal populations;
- Periodic algae blooms.

With proper management of N, inputs these trends can be reversed. Without proper management, more severe problems might develop, including:

- Periodic fish kills;
- Unpleasant odors and scum;
- Benthic communities reduced to the most stress-tolerant species, or in the worst cases, near loss of the benthic animal communities.

Coastal communities, including Falmouth, rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings could lead to further loss of eelgrass and possible increases in macro-algae, a higher frequency of undesirable decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a further loss of benthic macroinvertebrates throughout most of the system. As a result of these environmental impacts, commercial and recreational uses of the Wild Harbor estuarine system will be greatly reduced.

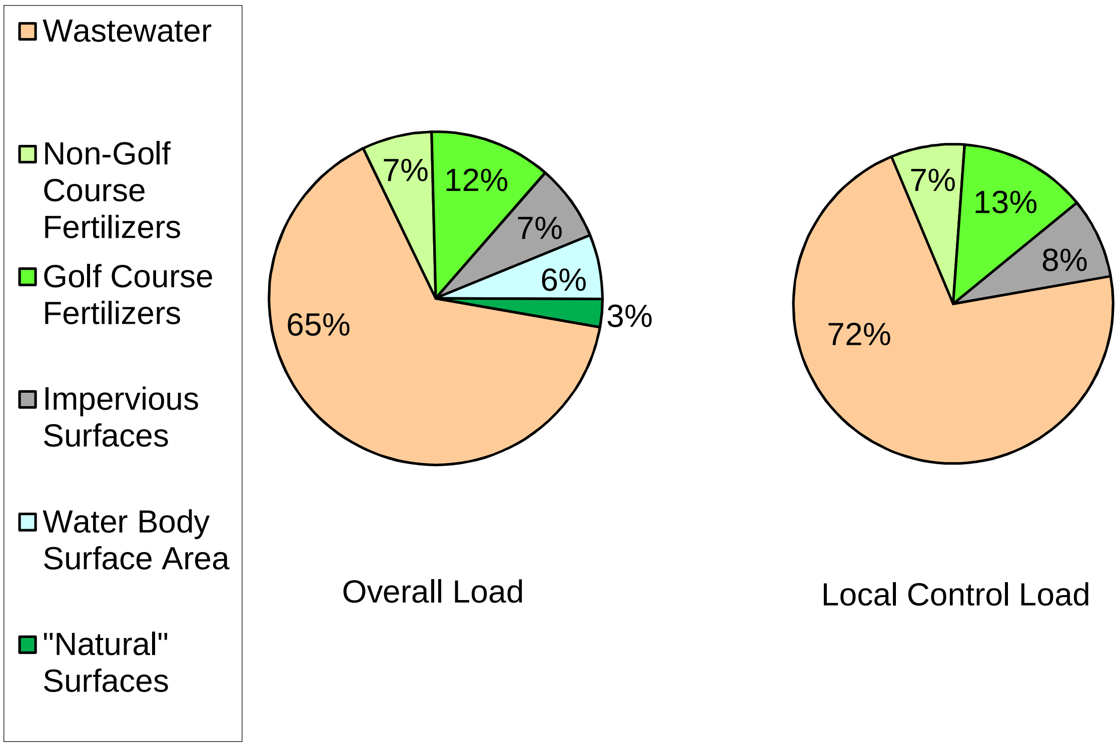
Sources of Nitrogen

Nitrogen enters the waters of coastal embayments/ponds from the following sources:

- The watershed
    - on-site subsurface wastewater disposal (septic) systems
    - natural background
    - runoff from impervious surfaces
    - fertilizers
    - wastewater treatment facilities (WWTF)
    - landfills
    - agricultural activities
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments/ponds

Figure ES-A below indicates the percent contributions of the various sources of N in the watershed to Wild Harbor. Values are based on Table ES-1 and Table 3 from the Massachusetts Estuaries Project (MEP) Technical Report (Howes *et. al*, 2013). As evident from this figure, most of the controllable N load to Wild Harbor originates from septic systems.

Figure ES-A: Percent Contributions of All Watershed Nitrogen Sources and Percent Contributions of Controllable Nitrogen Sources to Wild Harbor



Target Threshold Nitrogen Concentrations and Loadings

The Wild Harbor estuarine system is located entirely within the Town of Falmouth on Cape Cod, Massachusetts. The watershed of this system is predominately in Falmouth but very small portions are shared between the Towns of Bourne and Sandwich. The N that enters the estuary each day (N load) is 23.66 kg/day from the combined three major subwatersheds (Dam Pond Stream, Wild Harbor River and Wild Harbor). The resultant average annual concentration of N in Wild Harbor inner harbor, or Boat Basin, was 0.439 mg/L (milligrams per liter of N) and for Wild Harbor River was 0.480 mg/L (average of yearly means at the two stations collected from 1999 – 2009 as reported in Table VI-1 of the MEP Technical Report and included in Appendix B of this report).

In order to restore and protect this estuarine system, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below the thresholds that cause the observed environmental impacts. This concentration will be referred to as the *target threshold N concentration*. It is the goal of the TMDL to reach this target threshold N concentration, as it has been determined for each impaired waterbody segment. The MEP has determined that a N concentration of 0.35 mg/L for this estuarine system at the sentinel station (WH-1) at the outlet of Boat Basin will restore eelgrass habitat in the main Wild Harbor basin. In addition, restoration of benthic habitat for infaunal animals will occur as management alternatives are implemented for eelgrass. Based on sampling and modeling analysis and the resulting Technical Report, the MEP has determined that the Total Maximum Daily Load (TMDL) of N to meet the target threshold N concentration of 0.35 mg/L is 17.60 kg N/day for the entire system. The mechanism for achieving these target threshold N concentrations is to reduce the N loadings to the Wild Harbor system. To meet the TMDL this report suggests that a 32% reduction of the total watershed nitrogen load for the entire system will be required.

This document presents the TMDL for this water body and provides guidance to the community of Falmouth on possible ways to reduce the N loadings to within the recommended TMDL and protect the waters of this estuarine system.

Wild Harbor (MA95-20) has a TMDL for Fecal Coliform (Category 4a, 2014 Integrated Report), but was found to be impaired for nutrients during the MEP study and has been assigned a TMDL in this report. Wild Harbor will be evaluated for nutrient impairment in a future 303(d) listing by MassDEP. Wild Harbor River (MA95-68) has a TMDL for Fecal Coliform (Category 4a). Wild Harbor River is listed (Category 5) for Nutrient/Eutrophication Biological Indicators, although it was determined to be meeting Aquatic Life Use during the course of the MEP study based on benthic habitat data. Wild Harbor River and Dam Pond Stream, (no assessment unit ID) are hydraulically connected to Wild Harbor and therefore have been assigned Protective TMDLs.

Implementation

The primary goal of the TMDL implementation will be lowering the concentrations of N in Wild Harbor. The MEP linked model has shown that by reducing the loadings from on-site subsurface wastewater disposal systems in the watershed by 43% this target threshold concentration can be met. It is important to note that there is a variety of loading reduction scenarios that could achieve the target threshold N concentration. Implementing best management practices (BMPs) to reduce N loadings from fertilizers and runoff where possible will also help to lower the total N load to this system.

Local officials can explore other loading reduction scenarios through additional modeling as part of their Comprehensive Wastewater Management Plan (CWMP). Implementing best management practices (BMPs) to reduce N loadings from fertilizers and runoff where possible will also help to lower the total N load to the system. Methodologies for reducing N loading from septic systems, storm water runoff and fertilizers are provided in detail in the "MEP Embayment Restoration and Guidance for Implementation Strategies", available on the MassDEP website: http://www.mass.gov/eea/agencies/massdep/water/watersheds/coastal-resources-and-estuaries.html. The appropriateness of any of the alternatives will depend on local conditions, and will have to be determined on a case-by-case basis, using an adaptive management approach. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under Clean Water Act Section 208. Finally, growth within the community of Falmouth which would exacerbate the problems associated with N loading should be guided by considerations of water quality-associated impacts.

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state (1) to identify waters that are not meeting water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. The TMDL allocation establishes the maximum loadings of these pollutants of concern, taking into consideration all contributing sources to that water body, while allowing the system to meet and maintain its water quality standards and designated uses, including compliance with numeric and narrative standards. The TMDL development process may be described in four steps, as follows:

1. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses.

2. Assessment of present water quality conditions in the water body, including estimation of present loadings of pollutants of concern from both point sources (discernable, confined, and concrete sources such as pipes) and non-point sources (diffuse sources that carry pollutants to surface waters through runoff or groundwater).

3. Determination of the loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. If the water body is not presently meeting its designated uses, then the loading capacity will represent a reduction relative to present loadings.

4. Specification of load allocations based on the loading capacity determination for non-point sources and point sources that will ensure that the water body will not violate water quality standards.

After public comment and final approval by the EPA, the TMDL will serve as a guide for future implementation activities. The MassDEP will work with the Town of Falmouth to develop specific implementation strategies to reduce N loadings and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the Wild Harbor system the pollutant of concern for this TMDL (based on observations of eutrophication) is the nutrient nitrogen (N). Since nitrogen is the limiting nutrient in coastal and marine waters, as its concentration increases, so does plant productivity. This leads to nuisance populations of macro-algae and increased concentrations of phytoplankton and epiphyton that imperil the healthy ecology of the affected water bodies.

The TMDL for total N for the Wild Harbor system is based primarily on data collected, compiled and analyzed by University of Massachusetts Dartmouth’s School for Marine Science and Technology (SMAST), the Cape Cod Commission, Buzzards Bay Coalition’s Baywatchers Monitoring Program and others, as part of the Massachusetts Estuaries Project (MEP). The data were collected over a study period from 1999 to 2009. This study period will be referred to as the “Present Conditions” in the TMDL since it contains the most recent data available. The MEP Technical Report can be found at http://bit.ly/MassEstuariesProject. The MEP Technical Report presents the results of the analyses of this coastal embayment system using the MEP Linked Watershed-Embayment Nitrogen Management Model (Linked Model).

The analyses were performed to assist Falmouth with decisions on current and future wastewater planning, wetland restoration, anadromous fish runs, shellfisheries, open-space and harbor maintenance programs. Critical elements of this approach are the assessments of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements and benthic community structure that were conducted on this embayment. These assessments served as the basis for generating a N loading threshold for use as a goal for watershed N management. The TMDL is based on the site-specific target threshold N concentration generated for this embayment. Thus, the MEP offers a science-based management approach to support the wastewater management planning and decision-making process in the Town of Falmouth.

Description of Water Bodies and Priority Ranking

The Wild Harbor Estuarine System is located within the Town of Falmouth on Cape Cod Massachusetts. This system is located on the eastern shore of Buzzards Bay between Megansett Harbor and West Falmouth Harbor. The Wild Harbor system is a complex estuary comprised of a large outer basin constrained by Nyes Neck to the north and Crow Point to the south, with two contributory basins: a small inner basin to the northeast of the main harbor and a tidal river dominated by salt marsh flowing into the main harbor from the southeast (Figure 2). The Wild Harbor inner basin, or Boat Basin, is the main mooring area in the Wild Harbor System with ~100 boat moorings and other boat activities, many associated with the Wild Harbor Yacht Club. The tidal river, Wild Harbor River, contains most of the 110 acres of salt marsh within the Wild Harbor System. Fresh water ponds (Dam Pond, Noname Pond, and Potter’s Pond) are located in Upper Wild Harbor River.

The developed regions of the watershed to the Wild Harbor embayment system are distributed almost entirely within the Town of Falmouth. The upper most portion of the watershed also falls within Sandwich and Bourne, however this portion of the watershed is mostly undeveloped. The major stakeholder for management and restoration of Wild Harbor is the Town of Falmouth.

The MEP team has delineated a watershed area of approximately 3.3 square miles for the Wild Harbor system. The delineated contributory watershed includes eight subwatersheds which were delineated for estimation of groundwater flows and nutrient export (Figure 1, Howes *et. al*, 2013, pg. 26). The MEP team has estimated a total groundwater flow for the system of 13,969 m^3/day.

In the overall Wild Harbor watershed, the predominant land use based on area is residential use, which accounts for 37% of the overall watershed area while public service lands represent the second highest percentage (33%) of watershed area (Howes *et. al* 2013, pg 33). Overall, undeveloped lands account for 13% of the entire Wild Harbor watershed area.

A more complete description of this estuarine system is presented in Chapters I and IV of the MEP Technical Report (Howes *et. al* 2013). A majority of the information presented here on this estuarine system is drawn from the Technical Report. Chapters VI and VII of the MEP Technical Report provide assessment data that show that the Wild Harbor estuarine system is impaired because of nutrients, low dissolved oxygen levels, elevated chlorophyll-*a* levels, eelgrass loss and benthic fauna habitat degradation.

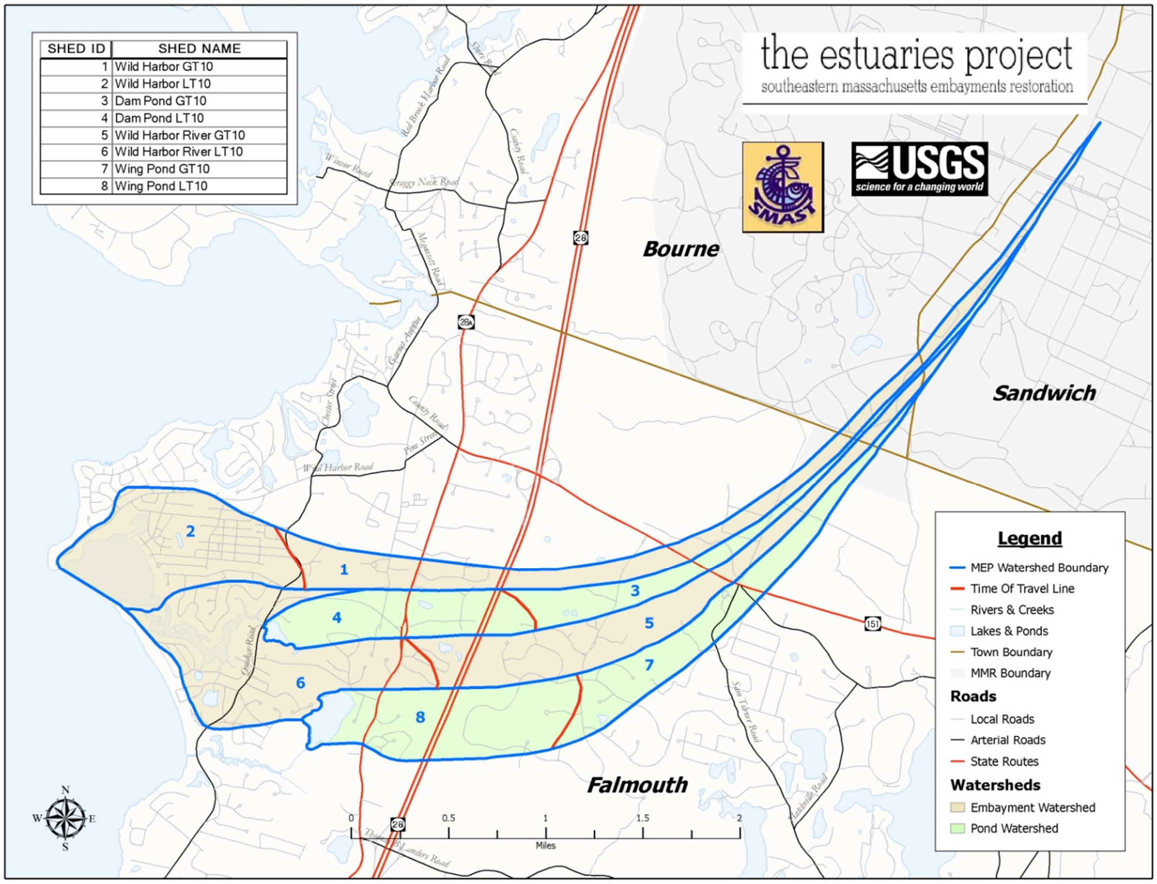

Figure 1: Wild Harbor Watershed Area Delineation (Howes et. al 2013, pg. 25)

The nature of enclosed embayments in populous regions brings two opposing elements to bear: 1) as protected marine shoreline they are popular regions for boating, recreation, and land development and 2) as enclosed bodies of water, they may not be readily flushed of the pollutants that they receive due to the proximity and density of development near and along their shores. The Wild Harbor system is at risk of further eutrophication from high nutrient loads in the groundwater and runoff from the watershed.

Wild Harbor estuary currently supports relatively healthy habitat, however, it appears to be beyond its ability to assimilate additional nutrients without impacting ecological health. The Wild Harbor system is at risk of further eutrophication from high nutrient loads in the groundwater and runoff from the watershed. This estuarine system has been assessed by MassDEP and is listed as a waterbody with a TMDL for fecal coliform (Category 4a - TMDL completed, EPA TMDL #36172) in the MA 2014 Integrated List of Waters (MassDEP 2015). It was also found to be impaired for nutrients, low dissolved oxygen, elevated chlorophyll *a*, loss of eelgrass, and degradation of benthic infauna habitat during the course of the MEP study (Table 1).

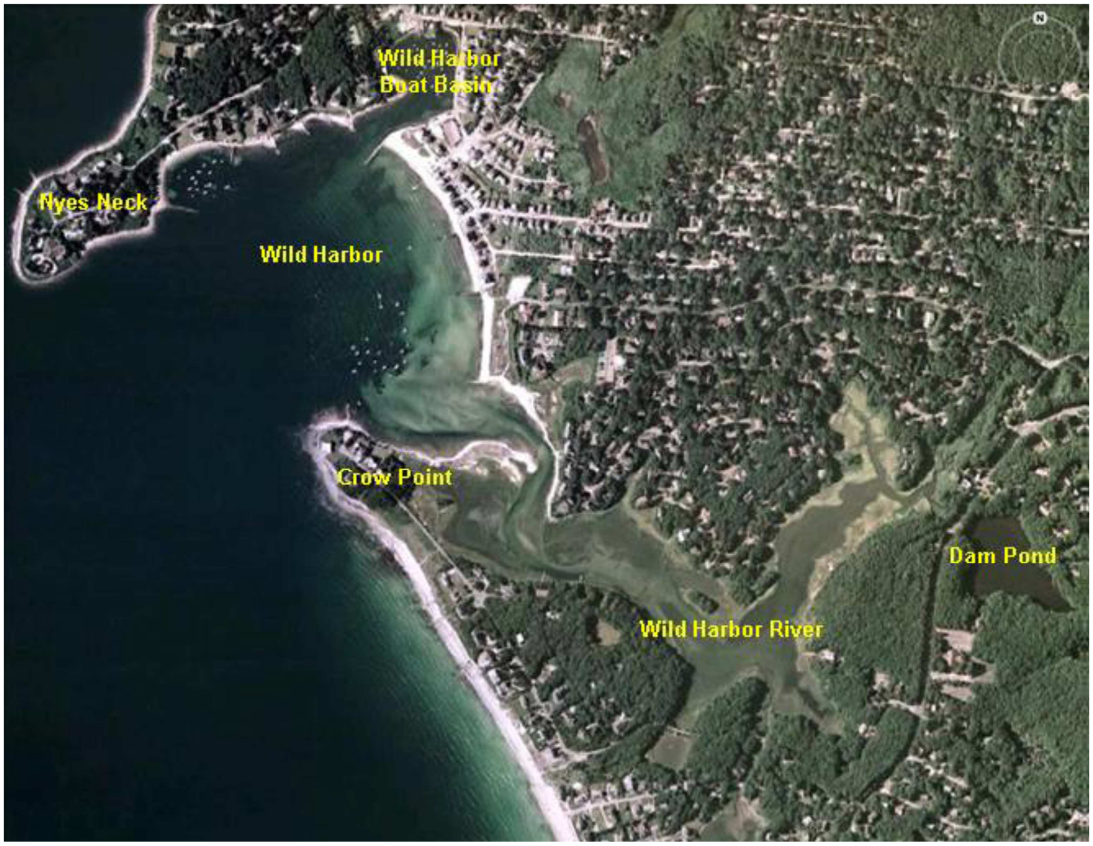

Figure 2: Overview of Wild Harbor (Howes et. al 2013, pg 2)

Priority Ranking

The embayment addressed by this TMDL is determined to be a high priority based on three significant factors: (1) the initiative that the town has taken to assess the conditions of the entire estuarine system; (2) the ~~commitment~~ support of the ~~made by the~~ town to restore and preserve the embayment; and (3) the extent of impairment in the embayment. In particular, this embayment is at risk of further degradation from increased N loads entering through groundwater and surface water runoff from the increasingly developed watershed. In both marine and freshwater systems an excess of nutrients results in degraded water quality, adverse impacts to ecosystems and limits on the use of water resources. Observations are summarized in Table 2 and the Problem Assessment section below and detailed in Chapter VII- Assessment of Embayment Nutrient Related Ecological Health of the MEP Technical Report.

Table 1: Comparison of DEP and SMAST Impaired Parameters for Wild Harbor System

System Component	MassDEP Waterbody Segment ID	MassDEP Segment Description	Class	2014 Integrated List Category	SMAST Impaired Parameter[1]	Size (acres)
Wild Harbor	MA95-20	Falmouth.	SA (Shellfish-ing)	4A (Fecal Coliform; EPA TMDL #36172)	Eelgrass loss, Nutrients, Dissolved Oxygen, Chlorophyll *a*, Benthic Fauna	84.15
Wild Harbor River	MA95-68	Headwaters, Falmouth to mouth at Wild Harbor, Falmouth.	SA (Shellfish-ing)	5 (Fecal Coliform; EPA TMDL #36172) Nutrient/Eutrophi-cation Biological Indicators)[3]	None, healthy	36.32
Dam Pond Stream[2]	*not assigned*					

[1] As determined by the MEP Wild Harbor Study and reported in the Technical Report, Howes *et al*, 2013.
[2] Freshwater, tributary to Wild Harbor River
[3] Determined not impaired for Nutrient/Eutrophication Biological Indicators. This segment will be evaluated for delisting in a future 303(d) List of Waters. Wild Harbor River has been assigned a Protective TMDL (Appendix D).

Description of Hydrodynamics of the Wild Harbor System

Wild Harbor is a fairly deep coastal embayment with the main Harbor having an average depth of -9 feet mean low tide (MLW). The harbor has a wide opening to the Buzzards Bay between Nyes Neck and Crow Point. The MEP project has evaluated the tidal circulation and flushing characteristics of this embayment system using both direct measurements and the RMA-2 model, a well-established model for estuaries. The MEP project deployed five gaging stations throughout the Wild Harbor system and one in Buzzards Bay to evaluate tidal characteristics. Little tidal dampening was found between Buzzards Bay and inner Wild Harbor or Wild Harbor River. In addition the phase delay of the main tidal constituent (lunar, twice per day tide, aka M2) was only approximately 16 minutes between Buzzards Bay and upper Wild Harbor River. The MEP project also determined a system residence time of one day for this system. Given these facts, Howes *et. al* (2013) found this system flushes well.

Problem Assessment

Wild Harbor is a moderately nutrient impacted shallow coastal estuarine system in the initial stages of nutrient impairment, as evidenced by the slow decline of eelgrass habitat. The main basin of Wild Harbor continues to support extensive eelgrass beds but eelgrass acreage has declined 48% between 1951 and 2006. The presence of eelgrass is particularly important for Wild Harbor as fish and shellfish habitat, which in turn provide a source of larvae critical to coastal benthic animal and fish communities. Shellfishing within the Wild Harbor system is presently prohibited year round by the Massachusetts Division of Marine Fisheries as the result of a historic (1969) oil spill, as well as bacterial contamination from watershed runoff.

The primary ecological threat to Wild Harbor is degradation resulting from nutrient enrichment. Most of the total N load (65%) is from septic systems, with other "controllable" N contributions coming from runoff of impervious surfaces and fertilizers. Other sources that are not locally controllable include atmospheric deposition to the surface of the estuary and natural surfaces. Nitrogen from these sources enters the groundwater and eventually enters the estuary system.

The Town of Falmouth has grown rapidly over the past four decades. In the period from 1970 to 2010 the number of year round residents in Falmouth has almost doubled (Figure 3). The watershed of Wild Harbor has had rapid and extensive development of single-family homes and the conversion of seasonal into full time residences. Water quality problems associated with this development result primarily from on-site wastewater treatment systems and to a lesser extent from fertilizers and runoff from these developed areas. The remaining build-out potential within the Wild Harbor watershed will increase unattentuated system-wide nitrogen loading by only about 6%. At the time of the data collection 100% of the parcels in the Wild Harbor watershed relied on privately maintained septic systems for on-site treatment and disposal of wastewater. The Silver Beach sewer project (completed after the period of data collection used in the MEP) will fulfill 8.5 % of the nitrogen load reduction needed to restore the nitrogen impaired habitats within the Wild Harbor System.

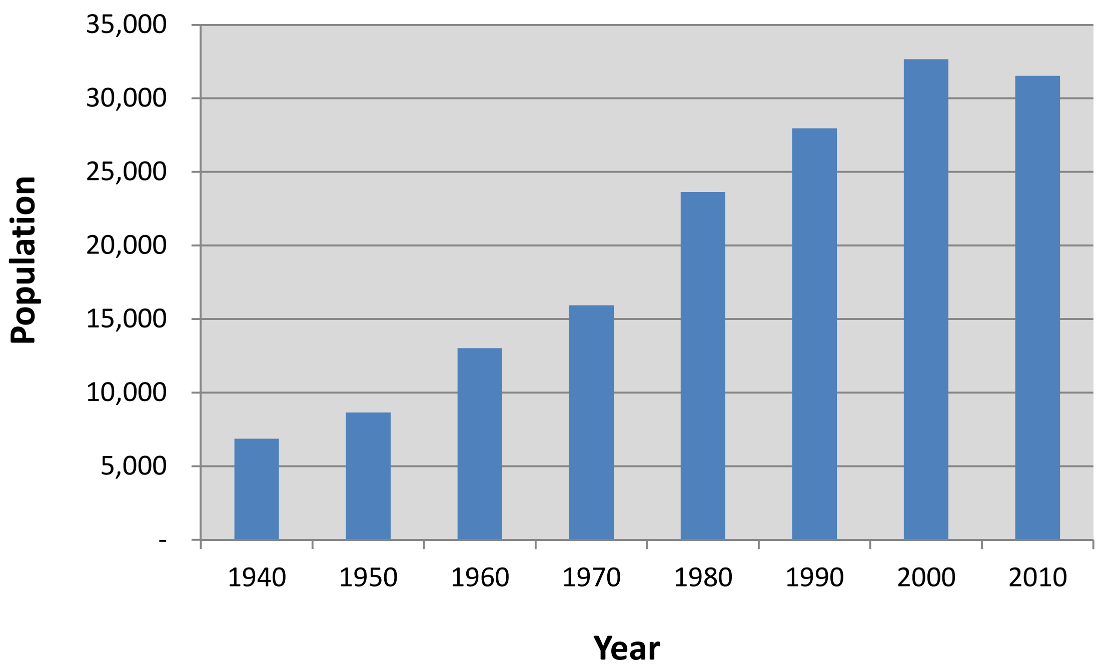

Figure 3: Falmouth Historic Residential Population

Prior to the 1970s there were fewer homes and many of those were seasonal. It is generally recognized that declines in water and habitat quality often parallel population growth in the watershed. The problems in Wild Harbor include a temporal trend in loss of eelgrass from the inner margin of the main basin, at the inner Boat Basin boundary and losses at the deeper margin of the Nyes Neck beds. Both the location and the temporal trend are consistent with nitrogen enrichment with significant decrease in diversity and quantity of benthic animals, decrease in eelgrass coverage and moderate levels of phytoplankton and patches of accumulated mats of macro algae (Table 2). If the N concentration continues to increase, future habitat degradation could include periodic fish kills, unpleasant odors and scums and near loss of the benthic community and/or presence of only the most stress-tolerant species of benthic animals.

Coastal communities, including Falmouth, rely on clean, productive and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as commercial fin fishing and shellfishing. The continued degradation of this coastal embayment, as described above, could significantly reduce the recreational and commercial value and use of these important environmental resources.

Habitat and water quality assessments were conducted on this estuarine system based upon water quality monitoring data, analysis of historical changes in eelgrass distribution, time-series water column dissolved oxygen and chlorophyll *a* measurements, benthic community structure assessments and sediment characteristics. At present, the Wild Harbor Estuary is beyond its ability to assimilate nitrogen without impairment and is showing low to moderate levels of nitrogen enrichment, with some moderate impairment of both eelgrass in the main basin of Wild Harbor and significant impairment of infaunal habitats in the inner Boat Basin.

Table 2: General Summary of Conditions Related to the Major Indicators of Habitat Impairment Observed in the Wild Harbor System[1]

Dissolved Oxygen	Chlorophyll *a*[2]	Macroalgae	Eelgrass Loss	Benthic Fauna[3]
Oxygen depletion frequently <6 mg/L, periodically 3 mg/L **MI***	Moderate levels, average <10 µg/L, blooms 20-30 ug/L **MI***	Sparse drift algae, significant algal mats **MI/SI***	Loss of eelgrass habitat between Wild Harbor and Boat Basin and deep margin of the Nyes Neck beds **MI***	Low numbers species, moderate number of individuals, mostly stress tolerant **SI***

[1] Assessment refers to Inner Boat Basin of the Wild Harbor. x The Outer Basin was assessed as MI for eelgrass and H/MI for Benthic Infauna.
[2] Algal blooms are consistent with chlorophyll *a* levels above 20 µg/L
[3] Based on observations of the types of species, number of species, and number of individuals
H - Healthy habitat conditions
MI – Moderately Impaired
SI – Significantly Impaired - considerably and appreciably changed from normal conditions
SD – Severely degraded
* These terms are more fully described in MEP report "Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators" December 22, 2003.
http://www.mass.gov/eea/docs/dep/water/resources/n-thru-y/nitroest.pdf

Pollutant of Concern, Sources and Controllability

In Wild Harbor, as in most marine and coastal waters, the limiting nutrient is nitrogen (N). Nitrogen concentrations above those expected naturally contribute to undesirable water quality and habitat conditions (such as described above).

Wild Harbor has had extensive data collected and analyzed through the MEP, with the cooperation and assistance from the Town of Falmouth, Buzzards Bay Coalition's Baywatchers Monitoring Program and the Cape Cod Commission (CCC). Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the MEP Technical Report. These investigations revealed that loadings of nutrients, especially N, are much larger than they would be under natural conditions and, as a result, the water quality has deteriorated. Figure 4 illustrates the sources and percent contributions of sources of N into Wild Harbor.

The level of "controllability" of each source, however, varies widely as shown in Table 3 below. Cost/benefit analyses will have to be conducted for all possible N loading reduction methodologies in order to select the optimal control strategies, priorities, and schedules.

Table 3: Sources of Nitrogen and their Controllability

Nitrogen Source	Degree of Controllability at Local Level	Reasoning
Agricultural fertilizer and animal wastes	Moderate	These nitrogen loadings can be controlled through appropriate agricultural Best Management Practices (BMPs).
Atmospheric deposition to the estuary surface	Low	It is only through region- and nation-wide air pollution control initiatives that significant reductions are feasible. Local control although helpful is not adequate.
Atmospheric deposition to natural surfaces (forests, fields, freshwater bodies) in the watershed	Low	Atmospheric deposition (loadings) to these areas cannot adequately be controlled locally. However, the N from these sources might be subjected to enhanced natural attenuation as it moves toward the estuary.
Fertilizer	Moderate	Lawn and golf course fertilizer and related N loadings can be reduced through BMPs, bylaws and public education.
Septic system	High	Sources of N can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations, transporting and treating septage at treatment facilities with N removal technology either in or out of the watershed, or installing N-reducing on-site wastewater treatment systems.
Sediment	Low	N loadings are not feasibly controlled on a large scale by such measures as dredging. However, the concentrations of N in sediments, and thus the loadings from the sediments, will decline over time if sources in the watershed are removed, or reduced to the target levels discussed later in this document. In addition, increased dissolved oxygen will help keep N from fluxing.
Stormwater runoff from impervious surfaces	Moderate	This nitrogen source can be controlled by BMPs, bylaws and stormwater infrastructure improvements and public education. Stormwater NPDES permit requirements help control stormwater related N loadings in designated communities.
Wastewater treatment facility (WWTF)	High	Wastewater treatment facilities as point sources of pollution to surface water are permitted under the National Pollution Discharge Elimination System. Treated wastewater effluent discharged to groundwater disposal systems are permitted by MassDEP. There is a high degree of regulatory certainty that within the limits of technology, nutrient sources at these facilities can be controlled.

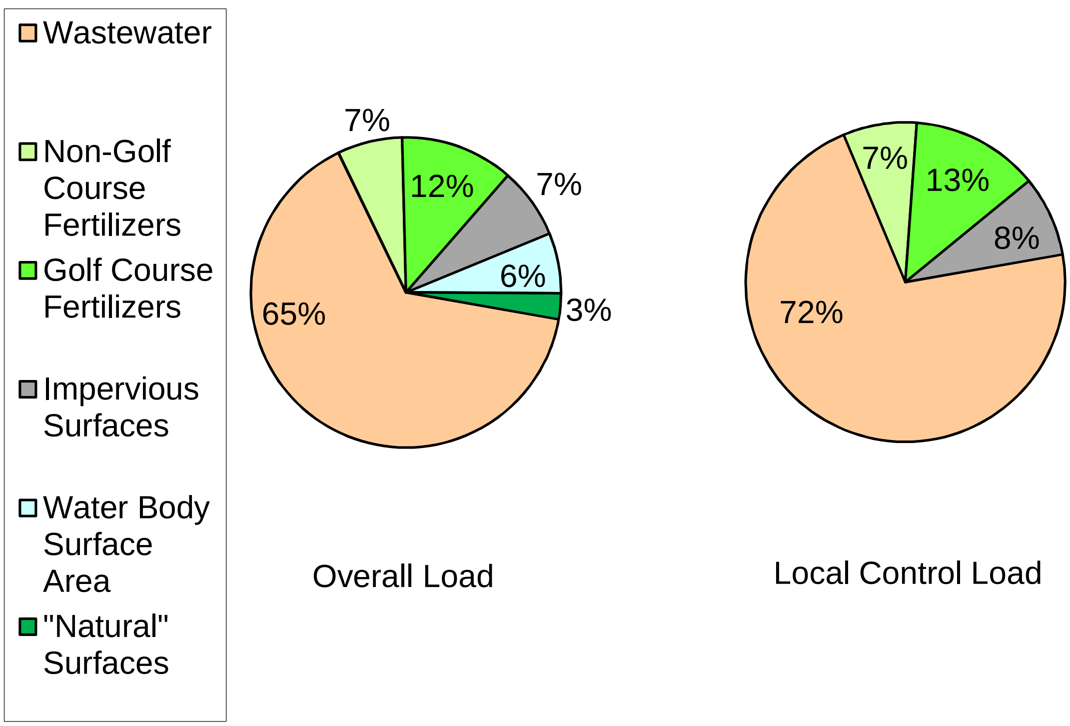

Figure 4: Percent Contribution of Watershed Nitrogen Sources to Wild Harbor System (Howes *et al*, 2013)

Description of the Applicable Water Quality Standards

Wild Harbor and Wild Harbor River are classified as Class SA waterbodies in the Massachusetts Water Quality Standards (MassDEP 2007). Freshwater portions of the system are classified as B. Massachusetts currently has narrative standards for nutrients (nitrogen and phosphorus) for waters of the Commonwealth such that "all surface waters shall be free of nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed site specific criteria developed in a TMDL or otherwise, established by the department" (MassDEP 2007). A more through explanation of applicable standards can be found in Appendix A.

Thus, the assessment of eutrophication is based on site-specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the US Environmental Protection Agency in their Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (EPA-2001). The guidance manual notes that lakes, reservoirs, streams, and rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management. However, individual estuarine and coastal marine waters tend to have unique characteristics, and development of individual water body criteria is typically required.

Methodology - Linking Water Quality and Pollutant Sources

Extensive data collection and analyses have been described in detail in the MEP Technical Report. These data were used by SMAST to assess the loading capacity of each sub-embayment. Physical (Chapter V), chemical, and biological (Chapters IV, VII, and VIII**)** data were collected and evaluated. The primary water quality objective was represented by conditions that:

1) Restore the natural distribution of eelgrass because it provides valuable habitat for shellfish and finfish;

2) Prevent algal blooms;

3) Restore and protect benthic communities; and

4) Maintain dissolved oxygen concentrations that are protective of the estuarine communities.

The details of the data collection, modeling and evaluation are presented and discussed in Chapters IV, V, VI, VII and VIII of the MEP Technical Report. The main aspects of the data evaluation and modeling approach of this study are summarized below.

The core analytical method of the Massachusetts Estuaries Project is the Linked Watershed-Embayment Management Modeling Approach. It fully links watershed inputs with embayment circulation and N characteristics and is characterized as follows:

- Requires site specific measurements within the watershed and each sub-embayment;
- Uses realistic "best-estimates" of N loads from each land-use (as opposed to loads with built-in "safety factors" like Title 5 design loads);
- Spatially distributes the watershed N loading to the embayment;
- Accounts for N attenuation during transport to the embayment;
- Includes a 2D or 3D embayment circulation model depending on embayment structure;
- Accounts for basin structure, tidal variations, and dispersion within the embayment;
- Includes N regenerated within the embayment;
- Is validated by both independent hydrodynamic, N concentration, and ecological data;
- Is calibrated and validated with field data prior to generation of "what if" scenarios.

The Linked Model has previously been applied to watershed N management in numerous embayments throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated and has use as a management tool for evaluating watershed N management options.

The Linked Model, when properly calibrated and validated for a given embayment, becomes a N management planning tool as described in the model overview below. The model can assess solutions for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. Also, since the Linked Model uses a holistic approach that incorporates the entire watershed, embayment and tidal source waters, it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries. It should be noted that this approach includes high-order, watershed and sub-watershed scale modeling necessary to develop critical nitrogen targets for each major sub-embayment. The models, data and assumptions used in this process are specifically intended for the purposes stated in the MEP Technical Report, upon which this TMDL is based. As such, the Linked Model process does not contain the type of data or level and scale of analysis necessary to predict the fate and transport of nitrogen through groundwater from specific sources. In addition, any determinations related to direct and immediate hydrologic connection to surface waters are beyond the scope of the MEP's Linked Model process.

The Linked Model provides a quantitative approach for determining an embayment's: (1) N sensitivity; (2) N threshold loading levels (TMDL); and (3) response to changes in loading rate. The approach is fully field validated and unlike many approaches, accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics (Figure I-~~3~~ 2 of the MEP Technical Report). This methodology integrates a variety of field data and models, specifically:

• Monitoring - multi-year embayment nutrient sampling;

• Hydrodynamics;
- Embayment bathymetry (depth contours throughout the embayment)
- Site-specific tidal record (timing and height of tides)
- Water velocity records (in complex systems only)
- Hydrodynamic model

• Watershed N Loading;
- Watershed delineation
- Stream flow (Q) and N load
- Land-use analysis (GIS)
- Watershed N model

• Embayment TMDL – Synthesis;
- Linked Watershed-Embayment N Model
- Salinity surveys (for linked model validation)
- Rate of N recycling within embayment
- Dissolved oxygen record
- Chlorophyll *a* record
- Eelgrass and Infaunal surveys

Application of the Linked Watershed-Embayment Model

The approach developed by the MEP for applying the linked model to specific embayments for the purpose of developing target threshold N loading rates includes:

1) Selecting one or two sub-embayments within the embayment system located close to the inland-most reach or reaches which typically has/have the poorest water quality within the system. These are called "sentinel" stations;

2) Using site-specific information and a minimum of three years of sub-embayment-specific data to select target threshold N concentrations for each sub-embayment. This is done by refining the draft target threshold N concentrations that were developed as the initial step of the MEP process. The target threshold N concentrations that were selected generally occur in higher quality waters near the mouth of the embayment system;

3) Running the calibrated water quality model using different watershed N loading rates, to determine the loading rate which will achieve the target threshold N concentration at the sentinel station. Differences between the modeled N load required to achieve the target threshold N concentration, and the present watershed N load represent N management goals for restoration and protection of the embayment system as a whole.

Previous sampling and data analyses and the modeling activities described above resulted in four major outputs that were critical to the development of the TMDL.
Two outputs are related to N **concentration**:

- the present N concentrations in the sub-embayments;
- site-specific target threshold N concentrations.

Two outputs are related to N **loadings:**

- the present N loads to the sub-embayments;
- load reductions necessary to meet the site specific target threshold N concentrations.

In summary, meeting the water quality standards by reducing the N concentration (and thus the N load) at the sentinel station(s), the water quality goals will be met throughout the entire system.

A brief overview of each of the outputs follows.

Nitrogen concentrations in the embayment

1) Observed "present" conditions:

Table 4 presents the average concentrations of N measured in this system from data collected at three stations during the period 1999 through 2009. Average yearly nitrogen concentrations at these two stations ranged from 0.378 – 0.596 mg/L with the lowest average concentration found in at the outlet of the inner Boat Basin (Station WH-1) and the highest average within the Wild Harbor River station (WH-2). See Figure 5 for station locations. The overall means and standard deviations of the averages are presented in Appendix B, Table B-1 (reprinted from Table VI-1 of the MEP Technical Report, Howes *et al*, 2013. The sentinel station is WH-1, located at the mouth of the Wild Harbor Boat Basin (Figure 5).

Table 4: Observed Present Nitrogen Concentrations and Sentinel Station Threshold Nitrogen Target Concentration for Wild Harbor.

Sub-Embayment	Station	**Mean**[1] (mg/L N)	Standard Deviation	Number Samples	Target Threshold Nitrogen Concentration (mg/L) [2]
Wild Harbor	WH-1	0.439	0.071	38	**0.35**
Wild Harbor River	WH-2	0.48	0.107	40	
Buzzards Bay	CBB1	0.282	0.044	13	

[1] Mean values are calculated as the average of the separate yearly means. Data collected in the summers of 1999 through 2009.
[2] Sentinel Station (WH-1) shown in Figure 5.

<u>2) Modeled site-specific target threshold N concentrations:</u>

A major component of TMDL development is the determination of the maximum concentrations of N (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. This is called the *target threshold nitrogen concentration*. Prior to conducting the analytical and modeling activities to determine this target threshold N concentration as described below, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators and N concentrations. The Linked Model was then used to determine site-specific threshold N concentrations by using the specific physical, chemical and biological characteristics of each sub-embayment.

Determination of the critical nitrogen threshold for maintaining high quality habitat within Wild Harbor is based primarily on the nutrient and oxygen levels, temporal trends in eelgrass distribution and benthic community indicators. The N threshold for Wild Harbor is based upon the goal of restoring eelgrass habitat within the main basin with the parallel goal of restoring benthic habitat for infaunal animals in the inner Wild Harbor Boat Basin.

As listed in Table 4 above, the site-specific target threshold N concentration is 0.35 mg/L. The findings of the analytical and modeling investigations to determine this target threshold nitrogen concentration for the estuarine system are discussed below.

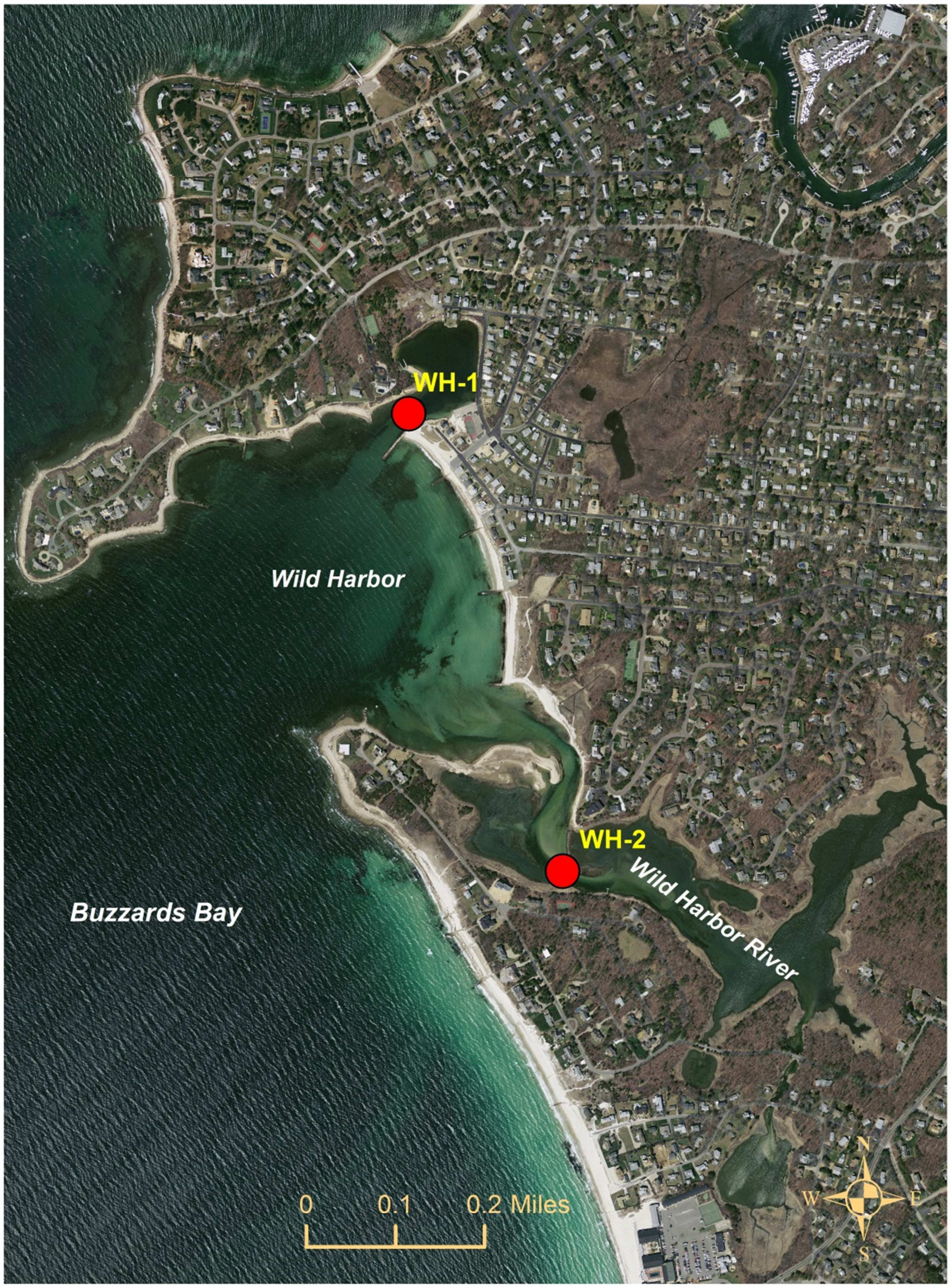

Figure 5: Wild Harbor Long Term Monitoring Stations. Sentinel Station is Station WH-1.

As previously described, the Wild Harbor estuarine system presently supports nitrogen related habitat impairment throughout the tidal reach. The Wild Harbor Embayment System presently shows a moderate impairment to eelgrass habitat within its outer basin, the main basin of Wild Harbor. The impairment is based upon the recent temporal trend in loss of eelgrass from the inner margin of the basin, at the inner Boat Basin boundary and loss at the deeper margin of the Nyes Neck beds. Both the location and the temporal trend are consistent with nitrogen enrichment. However, as the rate of loss has been gradual and significant eelgrass resources still exist, that indicates that this estuarine basin is only just beyond its nitrogen threshold (ie the level of nitrogen a system can tolerate without impairment.) The presence of stable dense eelgrass beds throughout the main basin of Wild Harbor and the generally high quality benthic animal habitat throughout the embayment system (except for the Boat Basin) also indicates a system just beyond its nitrogen enrichment threshold. The clear enrichment of the inner region (the boundary area losing eelgrass) and within the Boat Basin is consistent with habitat impairment documented for this estuary.

Total nitrogen levels (TN) within Wild Harbor, with its moderately stressed eelgrass beds, revealed summer-time, tidally-averaged, annual means of 0.439 - 0.48 mg/L N, (as reported in Chapter VI of the MEP Technical Report and reprinted in Appendix B). The MEP Technical Report concluded that Wild Harbor appears to be presently slightly beyond its nitrogen threshold for sustainable eelgrass coverage based on the levels of TN, moderate epiphyte growth, and the fact that eelgrass presently colonizes much of the main basin of Wild Harbor with temporal loss of bed coverage.

As eelgrass within the Wild Harbor Embayment System is a critical habitat structuring the productivity and resource quality of the entire system, and given that it is presently showing moderate impairment, restoration of this resource is the primary target for overall restoration of this system. Therefore to restore eelgrass habitat in Wild Harbor the nitrogen concentration (tidally averaged TN) at the sentinel location at the outlet of the Boat Basin (WH-1) needs to be lowered to 0.35 mg/L.

This threshold is similar to that for West Falmouth Harbor and Phinneys Harbor at similar depths and is focused in part on restoring eelgrass where it had persisted until recently near the tidal inlet to the Boat Basin. Lowering the level of nitrogen enrichment at the sentinel station will lower nitrogen levels within the Boat Basin and inner region of Wild Harbor with the parallel effect of improving impaired infaunal habitat. From the eelgrass surveys of 1951 and 2006, it appears that eelgrass coverage could increase by 10 acres or ~70% over the present bed area, with parallel restoration of the significantly impaired and degraded benthic animal habitat.

Nitrogen loadings to the embayment

<u>1) Present loading rates</u>:

In the Wild Harbor System overall the highest N loading from controllable sources is from on-site wastewater treatment systems which is almost always the highest N loading source in other coastal embayments as well. The MEP Technical Report calculates that septic systems account for 72% of the controllable N load to the overall system. Other controllable sources include fertilizers (20%), and runoff from impervious surfaces (8%) (Figure 4).The septic system loading is 17.36 kg N/day within the Wild Harbor watershed. The total N loading from all sources is 13.35 kg N/day. A further breakdown of N loading by source is presented in Table 5. The data on which Table 5 is based can be found in Table ES-1 of the MEP Technical Report.

Table 5: Present Attenuated Nitrogen Loading to the Wild Harbor Embayment System (from Howes *et. al*, 2013)

System Component	Present Land Use Load N[1] (kg/day)	Present Attenuated Septic System Load N (kg/day)	Present Total Attenuated Watershed Load N[3] (kg/day)	Direct Atmospheric Deposition N[4] (kg/day)	Present Net Benthic Flux N (kg/day)	Total N Load from All Sources[5] (kg/day)
Wild Harbor	2.83	7.50	10.33	1.03	-11.36	0.00
Wild Harbor River	3.01	8.81	11.83	0.45	-0.42	11.85
Dam Pond Stream	0.46	1.05	1.51	--	--	1.51
Wild Harbor(total system)	6.30	17.36	23.66	1.48	-11.78	13.35

[1] Present land use includes fertilizers, runoff from impervious surfaces, and atmospheric deposition to lakes and natural surfaces
[2] Includes atmospheric deposition to the estuary surface only.
[3] Composed of combined present land use, septic systems
[4] Atmospheric deposition to embayment surface only
[5] Composed of attenuated loadings from natural background, fertilizer, runoff from impervious surfaces, septic systems as well as atmospheric deposition and benthic flux loadings

As previously indicated, the present N loadings to Wild Harbor must be reduced in order to restore conditions and to avoid further nutrient-related adverse environmental impacts. The critical final step in the development of the TMDL is modeling and analysis to determine the loadings required to achieve the target threshold N concentrations.

2) Nitrogen loads necessary for meeting the site-specific target threshold N concentrations:

The nitrogen threshold developed by SMAST (Section VIII.2 in the MEP Technical Report) and summarized above was used to determine the amount of total nitrogen mass loading reduction required for restoration of eelgrass and infaunal habitats in the Wild Harbor system. Tidally averaged total nitrogen concentrations were used to calibrate the water quality model (Section VI in the MEP Technical Report). Modeled watershed nitrogen loads were sequentially lowered until the nitrogen levels reached the threshold level at the sentinel station chosen for Wild Harbor (WH-1). It is important to note that load reductions can be produced by reduction of any or all sources of N and/or by increasing the natural attenuation of nitrogen within the freshwater systems to the embayment. The load reductions presented here represent only one of a suite of potential reduction approaches that need to be evaluated by the community.

Table 6 includes the present and target threshold watershed N loadings to Wild Harbor and the percentage reduction necessary to meet the target threshold N concentration at the sentinel station (from Table ES-2 of the MEP Technical Report).

Table 6: Present Watershed Nitrogen Loading Rates, Calculated Loading Rates that are Necessary to Achieve Target Threshold Nitrogen Concentrations and the Percent Reductions of the Existing Loads Necessary to Achieve the Target Threshold Loadings

System Component	Present Attenuated Watershed Load[1] (kg/day)	Target Threshold Watershed Load[2] (kg/day)	Percent watershed reductions needed to achieve target threshold loads
Wild Harbor	10.33	4.55	-56%
Wild Harbor River	11.83	10.06	-15%
Dam Pond Stream	1.51	1.51	0%
Wild Harbor (total system)	23.66	16.12	-32%

[1] Composed of wastewater from septic systems, fertilizer, runoff from impervious surfaces, atmospheric deposition to freshwater waterbodies and natural surfaces. This load does not include direct atmospheric deposition onto estuarine surfaces or benthic regeneration.
[2] Target threshold watershed load is the load from the watershed needed to meet the embayment target threshold N concentration of 0.35 mg/L identified in Table 4 above.

Total Maximum Daily Loads

As described in EPA guidance, a total maximum daily load (TMDL) identifies the loading capacity of a water body for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. The TMDLs are established to protect and/or restore the estuarine ecosystem, including eelgrass, the leading indicator of ecological health, thus meeting water quality goals for aquatic life support. Because there are no "numerical" water quality standards for N, the TMDL for the Wild Harbor system is aimed at determining the loads that would correspond to specific N concentrations determined to be protective of the water quality and ecosystems.

The development of a TMDL requires detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time) for each waterbody system. The results of the mathematical model are correlated with estimates of impacts on water quality including negative impacts on eelgrass (the primary indicator), as well as dissolved oxygen, chlorophyll and benthic infauna.

The TMDL can be defined by the equation:

$$TMDL = BG + WLAs + LAs + MOS$$

Where:

TMDL = loading capacity of receiving water
BG = natural background
WLAs = portion allotted to point sources
LAs = portion allotted to (cultural) non-point sources
MOS = margin of safety

Background Loading

Natural background N loading is included in the loading estimates, but is not quantified or presented separately. Background loading was calculated on the assumption that the entire watershed is forested with no anthropogenic sources of N. It is accounted for in this TMDL but not defined as a separate component. Readers are referred to Table ES-1 of the MEP Technical Report for estimated loading due to natural conditions.

Waste Load Allocations

Waste load allocations (WLA) identify the portion of the loading capacity allocated to existing and future point sources of wastewater. In the Wild Harbor estuarine system there are no permitted surface water discharges in the watershed with the exception of stormwater. A TMDL may establish a specific WLA for an identified source or, as in the case of stormwater, may establish an aggregate WLA that applies to numerous sources. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of stormwater also be included in the waste load component of the TMDL. In the Wild Harbor estuarine system this load includes runoff from impervious surfaces.

For purposes of the Wild Harbor Estuarine System TMDL, MassDEP also considered the nitrogen load reductions from regulated MS4 sources necessary to meet the target nitrogen concentrations. In estimating the nitrogen loadings from regulated stormwater sources, MassDEP considered that most stormwater runoff in the MS4 communities is not discharged directly into surface waters, but, rather, percolates into the ground. The geology on Cape Cod and the Islands consists primarily of glacial outwash sands and gravels, and water moves rapidly through this type of soil profile. A systematic survey of stormwater conveyances on

Cape Cod and the Islands was never undertaken prior to the MEP study used in the development of this TMDL. Nevertheless, most catch basins on Cape Cod and the Islands are known to MassDEP to have been designed as leaching catch basins in light of the permeable overburden. MassDEP, therefore, recognized that most stormwater that enters a catch basin in the regulated area will percolate into the local groundwater table rather than directly discharge to a surface waterbody.

As described in the Methodology Section (above), the Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source. However, MassDEP also considered that some stormwater may be discharged directly to surface waters through outfalls. In the absence of specific data or other information to accurately quantify stormwater discharged directly to surface waters, MassDEP assumed that all impervious surfaces within 200 feet of the shoreline, as calculated from MassGIS data layers, would discharge directly to surface waters, whether or not it in fact did so. MassDEP selected this approach because it considered it unlikely that any stormwater collected farther than 200 feet from the shoreline would be directly discharged into surface waters. Although the 200 foot approach provided a gross estimate, MassDEP considered it a reasonable and conservative approach given the lack of pertinent data and information about stormwater collection systems on Cape Cod.

MassDEP has calculated the potential waste load allocation for this 200 foot buffer zone previously in a number of nitrogen TMDLs for embayments on Cape Cod. The calculated waste load allocation due to runoff from impervious surfaces within 200 feet of the estuary is 0.14 kg/day, 0.5% of the total unattenuated watershed load. (Refer to Appendix C for details.) This conservative load is obviously negligible when compared to other sources.

Load Allocations

Load allocations identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of the Wild Harbor system, the controllable nonpoint source loadings are primarily from on-site subsurface wastewater disposal systems. Additional N sources include stormwater runoff (except from impervious cover within 200 feet of the waterbody which is defined above as part of the waste load), fertilizers and atmospheric deposition.

Figure 4 (above) and Figure 6 (below) illustrate that septic systems are the most significant portion of watershed sources of controllable attenuated nitrogen (18.3 N/day), with fertilizers from lawns and golf courses a distant second (5.2 kg N/day). Another watershed source of controllable nitrogen is stormwater runoff, which contributes 2.1 kg N/day (from Table IV-3 in the MEP Technical Report). In addition, there are nonpoint sources of N from sediments, natural background and atmospheric deposition that are not feasibly controllable.

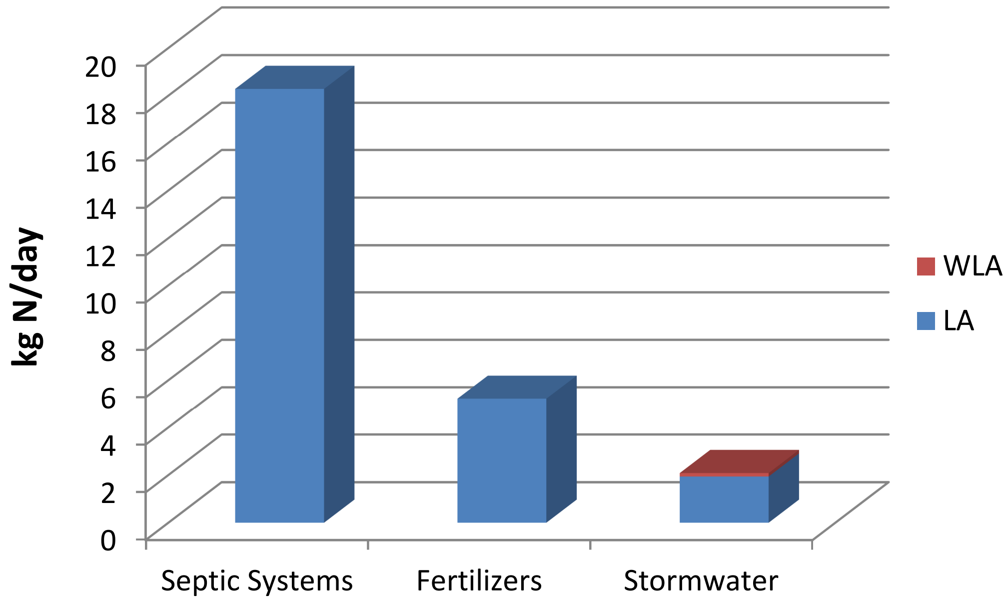

Figure 6: Controllable Watershed Sources of Nitrogen Loading to the Wild Harbor Estuarine System

Generally, storm water that is subject to the EPA Phase II Program would be considered a part of the waste load allocation rather than the load allocation. As presented in Chapters IV, V, and VI of the MEP Technical Report, on the Cape, the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater. As a result, the TMDL accounts for stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source, thus combining the assessments of wastewater and stormwater for the purpose of developing control strategies. Continued Phase II Program implementation in Falmouth, new studies and possibly further modeling will identify what portion of the stormwater load may be controllable through Best Management Practices (BMPs).

Sediment loading rates incorporated into the TMDL are different than the existing sediment flux rates because projected reductions of N loadings from the watershed will result in reductions of nutrient concentrations in the sediments, and therefore, over time, reductions in loadings from the sediments will occur. Benthic flux of nitrogen from bottom sediments is a critical (but often overlooked) component of nitrogen loading to the shallow estuarine systems, therefore determination of the site specific magnitude of this component was also performed (see Section VI of the MEP Report).

Benthic N flux is a function of N loading and particulate organic N (PON). Projected benthic fluxes are based upon projected PON concentrations and watershed N loads and are calculated by multiplying the present N flux by the ratio of projected PON to present PON using the following formulae:

$$\text{Projected N flux} = (\text{present N flux})\ (\text{PON projected} / \text{PON present})$$

When: $PON\ projected = (R_{load})\ (D_{PON})\ + PON_{present\ offshore}$

When $R_{load} =$ (projected N load) / (Present N load)

And D_{PON} is the PON concentration above background determined by:

$D_{PON} = (PON_{present\ embayment} - PON_{present\ offshore})$

Thus, benthic loading is affected by the change in watershed load. The benthic flux modeled for the Wild Harbor system is reduced (towards zero) from existing conditions based on the N load reduction from controllable sources. There was one exception to this rule. Since there was a negative benthic flux (nutrient uptake) recorded in the inlet to the Wild Harbor boat basin and in the Wild Harbor River under present conditions, a more conservative approach was used for these segments in the TMDL by assuming zero benthic flux for these segments in the future. This conservative approach was used and is considered part of the margin of safety in the TMDL. Since benthic loading varies throughout the year and the values shown represent "worst case" summertime conditions, loading rates are presented in kilograms per day.

The loadings from atmospheric sources incorporated into the TMDL are the same rates presently occurring because, as discussed above, significant control of atmospheric loadings at the local level is not considered feasible.

Margin of Safety

Statutes and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality [CWA para 303 (d)(20©, 40C.G.R. para 130.7©(1)].The MOS must be designed to ensure that any uncertainties in the data or calculations used to link pollutant sources to water quality impairment modeling will be accounted for in the TMDL and ensure protection of the beneficial uses. The EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. An explicit MOS quantifies an allocation amount separate from other Load and Wasteload Allocations. An explicit MOS can incorporate reserve capacity for future unknowns, such as population growth or effects of climate change on water quality. An implicit MOS is not specifically quantified but consists of statements of the conservative assumptions used in the analysis. The MOS for the Wild Harbor Estuarine System TMDL is implicit. MassDEP used conservative assumptions to develop numeric model applications that account for the MOS. These assumptions are described below, and they account for all sources of uncertainty, including the potential impacts of changes in climate.

While the general vulnerabilities of coastal areas to climate change can be identified, specific impacts and effects of changing estuarine conditions are not well known at this time (http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html). Because the science is not yet available, MassDEP is unable to analyze climate change impacts on streamflow, precipitation, and nutrient loading with any degree of certainty for TMDL development. In light of these uncertainties and informational gaps, MassDEP has opted to address all sources of uncertainty through an implicit MOS. MassDEP does not believe that an explicit MOS approach is appropriate under the circumstances or will provide a more protective or accurate MOS than the implicit MOS approach, as the available data simply does not lend itself to characterizing and estimating loadings to derive numeric allocations within confidence limits. Although the implicit MOS approach does not expressly set aside a specific portion of the load to account for potential impacts of climate change, MassDEP has no basis to conclude that the conservative assumptions that were used to develop the numeric model applications are insufficient to account for the lack of knowledge regarding climate change.

Conservative assumptions that support an implicit MOS:

1. Use of conservative data in the linked model

The watershed N model provides conservative estimates of N loads to the embayment. Nitrogen transfer through direct groundwater discharge to estuarine waters is based upon studies indicating negligible aquifer attenuation and dilution, i.e. 100% of load enters embayment. This is a conservative estimate of loading because studies have also shown that in some areas less than 100% of the load enters the estuary. Nitrogen from the upper watershed regions which travel through ponds or wetlands almost always enters the embayment via stream flow and is directly measured (over 12-16 months) to determine attenuation. In these cases, the land-use model has shown a slightly higher predicted N load than the measured discharges in the streams/rivers that have been assessed to date. Therefore, the watershed model as applied to the surface water watershed areas again presents a conservative estimate of N loads because the actual measured N in streams was lower than the modeled concentrations.

The hydrodynamic and water quality models have been assessed directly. In the many instances where the hydrodynamic model predictions of volumetric exchange (flushing) have also been directly measured by field measurements of instantaneous discharge, the agreement between modeled and observed values has been $\geq$92%. For the water quality model, it was possible to conduct a quantitative assessment of the model results as fitted to a baseline dataset - computed root mean squared (RMS) error is less than 0.01 mg/l, which demonstrates a good fit between modeled and measured data for this system (Howes *et. al* 2013, pg. 98). Since the water quality model incorporates all of the outputs from the other models, this excellent fit indicates a high degree of certainty in the final result. The high level of accuracy of the model provides a high degree of confidence in the output so less of a margin of safety is required.
In the Wild Harbor Estuarine System, there are two freshwater ponds with delineated watersheds: Dam Pond and Wing Pond. Neither pond had bathymetric data or sufficient water quality data collection. Water quality and flow data were collected at the Dam Pond stream gauge and as a result, MEP staff were able to estimate a 45% TN attenuation rate.

Wing Pond was assigned a 50% TN attenuation rate, similar to other MEP studies and considered conservative.

Similarly, the water column N validation dataset was also conservative. The model is calibrated to measured water column N and validated to salinity. However, the model predicts average summer N concentrations. The very high or low measurements are marked as outliers. The effect is to make the N threshold more accurate and scientifically defensible. If a single measurement two times higher than the next highest data point in the series raises the average 0.05 mg N/L, this would allow for a higher "acceptable" load to the embayment. Marking the very high outlier is a way of preventing a single and rare bloom event from changing the N threshold for a system. This effectively strengthens the data set so that a higher margin of safety is not required.

Finally, the predicted reductions of the amount of N released from the sediments are most likely underestimates, i.e. conservative. The reduction is based solely on a reduced deposition of particulate organic nitrogen (PON) due to lower primary production rates under the reduced N loading in these systems. As the N loading decreases and organic inputs are reduced it is likely that rates of coupled remineralization-nitrification, denitrification and sediment oxidation will increase. It was also conservatively assumed that the negative benthic flux in Wild Harbor and Wild Harbor River (-11.36 and -0.42 kg/day N, respectively) does not exist under future loading conditions and as such was designated as "0" for purposes of the TMDL.

Benthic regeneration of N is dependent upon the amount of PON deposited to the sediments and the percentage that is regenerated to the water column versus being denitrified or buried. The regeneration rate projected under reduced N loading conditions was based upon two assumptions:(1) PON in the embayment in excess of that of inflowing tidal water (boundary condition) results from production supported by watershed N inputs; and (2) Presently enhanced production will decrease in proportion to the reduction in the sum of watershed N inputs and direct atmospheric N input. The latter condition would result in equal embayment versus boundary condition production and PON levels if watershed N loading and direct atmospheric deposition could be reduced to zero (an impossibility of course). This proportional reduction assumes that the proportion of remineralized N will be the same as under present conditions, which is almost certainly an underestimate. As a result, future N regeneration rates are overestimated which adds to the margin of safety.

Finally, decreases in air deposition through continuing air pollution control efforts are unaccounted for this TMDL and provide another component of the margin of safety.

2. Conservative sentinel station/target threshold nitrogen concentration

Conservatism was used in the selection of the sentinel station and target threshold N concentration. The sites were chosen that had stable eelgrass or benthic animal (infaunal) communities, and not those just starting to show impairment, which would have slightly higher N concentration. Meeting the target threshold N concentration at the sentinel station will result in reestablishment of eelgrass and benthic habitat throughout the rest of the system.

3. Conservative approach

The target loads were based on tidally averaged N concentrations on the outgoing tide which is the worst case condition because that is when the N concentrations are the highest. The N concentrations will be lower on the flood tides; therefore, this approach is conservative.

Finally, the linked model accounted for all stormwater loadings and groundwater loadings in one aggregate allocation as a non point source and this aggregate load is accounted for in the load allocation. The method of calculating the WLA in the TMDL for regulated stormwater was conservative as it did not disaggregate this negligible load from the modeled stormwater LA, hence this approach further enhances the margin of safety.

In addition to the margin of safety within the context of setting the N threshold levels described above, a programmatic margin of safety also derives from continued monitoring of this embayment to support adaptive management. This continuous monitoring effort provides the ongoing data to evaluate the improvements that occur over the multi-year implementation of the N management plan. This will allow refinements to the plan to ensure that the desired level of restoration is achieved.

Seasonal Variation

Since the TMDLs for the waterbody segments are based on the most critical time period, i.e. the summer growing season, the TMDLs are protective for all seasons. The daily loads can be converted to annual loads by multiplying by 365 (the number of days in a year). Nutrient loads to the embayment are based on annual loads for two reasons. The first is that primary production in coastal waters can peak in both the late winter-early spring and in the late summer-early fall periods. Second, as a practical matter, the types of management necessary to control the N load do not lend themselves to intra-annual manipulation since a considerable portion of the N is from non-point sources. Thus, calculating annual loads is most appropriate, since it is difficult to control non-point sources of N on a seasonal basis and N sources can take considerable time to migrate to impacted waters.

TMDL Values for the Wild Harbor System

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of the embayment were calculated by considering all sources of N grouped by natural background, point sources and non-point sources. A more meaningful way of presenting the loadings data from an implementation perspective is shown in Table 6 and Appendix D.

Table 6: The Nitrogen Total Maximum Daily Load for the Wild Harbor System

System Component	Target Threshold Watershed Load[1] (kg N/day)	Atmospheric Deposition (kg N/day)	Load from Sediments[2] (kg N/day)	TMDL[3] (kg N/day)

Wild Harbor	4.55	1.03	0	5.58
Wild Harbor River[4]	10.06	0.45	0	10.51
Dam Pond Stream[4]	1.51	--	--	1.51
Wild Harbor (total system)	16.12	1.48	0	17.6

[1] Target threshold watershed load is the load from the watershed needed to meet the embayment target threshold nitrogen concentration identified in Table 3.
[2] Projected future flux (present rates reduced approximately proportional to watershed load reductions). (Negative fluxes set to zero.)
[3]Sum of target threshold watershed load and atmospheric deposition load and sediment load.
[4] Protective TMDLs have been assigned due hydraulic connection to Wild Harbor.

In this table N loadings from the atmosphere and from nutrient rich sediments are listed separately from the target watershed threshold loads. The watershed load is composed of atmospheric deposition to freshwater and natural surfaces along with locally controllable N from on-site subsurface wastewater disposal systems, storm water runoff, and fertilizer sources. In the case of the Wild Harbor System, the TMDL was calculated by projecting reductions in locally controllable watershed sources of N. The target load identified in this table represents one alternative loading scenario to achieve that goal but other scenarios may be possible and approvable as well. It must be demonstrated however, that any alternative implementation strategies will be protective of the entire embayment system. Once again the goal of this TMDL is to achieve the identified target threshold N concentration at the identified sentinel station.

Implementation Plans

The critical element of this TMDL process is achieving the sentinel station specific target threshold N concentration presented in Table 3. This is necessary for the restoration and protection of water quality, benthic invertebrate habitat, and eelgrass within the Wild Harbor System. In order to achieve these target threshold N concentrations, N loading rates must be reduced throughout the Wild Harbor system. Table 6 above lists the target threshold watershed N load for this system.

Septic Systems:
Because the vast majority of controllable N load is from individual septic systems for private residences, the Comprehensive Wastewater Management Plan (CWMP) should assess the most cost-effective options for achieving the target threshold N watershed loads, including but not limited to, sewering and treatment for N control of sewage and septage at either centralized or de-centralized locations, and denitrifying systems for all private residences. The CWMP should include a schedule of the selected strategies and estimated timelines for achieving those targets. However, the MassDEP realizes that an adaptive management approach may be used to observe implementation results over time and allow for adjustments based on those results. The appropriateness of any of the alternatives will depend on local conditions, and will have to be determined on a case-by-case basis, using an adaptive management approach. This adaptive management approach will incorporate the priorities

and concepts included in the updated area wide management plan established under the Clean Water Act Section 208.

The Silver Beach area is an embayment within the Wild Harbor River and is a densely populated residential neighborhood. The Silver Beach Wastewater Treatment Plant (WWTP) was completed in 2009 with the capacity to connect approximately 230 homes with an average wastewater discharge of approximately 13,000 gpd. The current conditions modeling of the Wild Harbor Estuaries System was completed prior to the completion of the Silver Beach WWTP. The wastewater loading from this wastewater treatment plant was including in the buildout modeling scenario. The Silver Beach WWTP fulfills 8.5% of the nitrogen load reduction needed to restore the nitrogen impaired habitats within the Wild Harbor System. The effluent from the treatment plant is discharged to the groundwater beneath the athletic fields at the elementary school.

Table 7 (from Table VIII-2 of the MEP Technical Report) summarizes the present loadings from septic systems and the reduced loads that would be necessary to achieve the target threshold N concentration in the Wild Harbor system under the scenario modeled here. A 43% reduction in present septic loading achieved the target threshold N concentration of 0.35 mg/L at the sentinel station (Station WH-1), time averaged over the summer period. This septic load change will result in a 31.9% decrease in the total watershed load to the Wild Harbor Estuary.

Table 7: Summary of the Present Septic System Loads and the Loading Reductions that Would be Necessary to Achieve the TMDL by Reducing Septic System Loads Alone.

System Component	Present Septic N Load (kg N/day)	Threshold Septic load (kg N/day)	Threshold Septic Load % Change
Wild Harbor	7.50	1.73	-77%
Wild Harbor River	8.81	7.05	-20%
Dam Pond Stream	1.05	1.05	0%
Wild Harbor (total system)	17.36	9.83	-43%

The above modeling results provide one scenario of achieving the threshold level for the sentinel site within the estuarine system. This example does not represent the only method for achieving this goal. The Town of Falmouth is encouraged to evaluate other load reduction scenarios and take any reasonable steps to reduce the controllable N sources.

Stormwater:
EPA and MassDEP authorized most of the watershed community of Falmouth for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. EPA and MassDEP reissued the MS4 permit in April 2016. The reissued permit takes effect on March 31, 2017. The NPDES permits

issued in Massachusetts do not establish numeric effluent limitations for stormwater discharges, rather, they establish narrative requirements, including best management practices, to meet the following six minimum control measures and to meet State Water Quality Standards.

1. Public education and outreach particularly on the proper disposal of pet waste,
2. Public participation/involvement,
3. Illicit discharge detection and elimination,
4. Construction site runoff control,
5. Post construction runoff control, and
6. Pollution prevention/good housekeeping.

As part of their applications for Phase II permit coverage, communities must identify the best management practices they will use to comply with each of these six minimum control measures and the measurable goals they have set for each measure. Therefore, compliance with the requirements of the Phase II stormwater permit in the towns of Falmouth, Bourne and Sandwich will contribute to the goal of reducing the nitrogen load as prescribed in this TMDL for the Wild Harbor estuarine system watershed.

Climate Change:
MassDEP recognizes that long-term (25+ years) climate change impacts to southeastern Massachusetts, including the area of this TMDL, are possible based on known science. Massachusetts Executive Office of Energy and Environmental Affairs 2011Climate Change Adaptation Report: http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html predicts that by 2100 the sea level could be from 1 to 6 feet higher than the current position and precipitation rates in the Northeast could increase by as much as 20 percent. However, the details of how climate change will affect sea level rise, precipitation, streamflow, sediment and nutrient loading in specific locations are generally unknown. The ongoing debate is not about whether climate change will occur, but the rate at and the extent to which it will occur and the adjustments needed to address its impacts. EPA's 2012 Climate Change Strategy (http://water.epa.gov/scitech/climatechange/upload/epa_2012_climate_water_strategy_full_report_final.pdf) states: "Despite increasing understanding of climate change, there still remain questions about the scope and timing of climate change impacts, especially at the local scale where most water-related decisions are made." For estuarine TMDLs in southeastern Massachusetts, MassDEP recognizes that this is particularly true, where water quality management decisions and implementation actions are generally made and conducted at the municipal level on a sub-watershed scale.

EPA's Climate Change Strategy identifies the types of research needed to support the goals and strategic actions to respond to climate change. EPA acknowledges that data are missing or not available for making water resource management decisions under changing climate conditions. In addition, EPA recognizes the limitation of current modeling in predicting the pace and magnitude of localized climate change impacts and recommends further exploration of the use of tools, such as atmospheric, precipitation and climate change models, to help states evaluate pollutant load impacts under a range of projected climatic shifts.

In 2013, EPA released a study entitled, "Watershed modeling to assess the sensitivity of streamflow, nutrient, and sediment loads to potential climate change and urban development in 20 U.S. watersheds." (National Center for Environmental Assessment, Washington D.C.; EPA/600/R-12/058F). The closest watershed to southeastern Massachusetts that was examined in this study is a New England coastal basin located between Southern Maine and Central Coastal Massachusetts. These watersheds do not encompass any of the watersheds in the Massachusetts Estuary Project (MEP) region, and it has vastly different watershed characteristics, including soils, geography, hydrology and land use – key components used in a modeling analysis. The initial "first order" conclusion of this study is that, in many locations, future conditions, including water quality, are likely to be different from past experience. However, most significantly, this study did not demonstrate that changes to TMDLs (the water quality restoration targets) would be necessary for the region. EPA's 2012 Climate Change Strategy also acknowledges that the Northeast, including New England, needs to develop standardized regional assumptions regarding future climate change impacts. EPA's 2013 modeling study does not provide the scientific methods and robust datasets needed to predict specific long-term climate change impacts in the MEP region to inform TMDL development.

MassDEP believes that impacts of climate change should be addressed through TMDL implementation with an adaptive management approach in mind. Adjustments can be made as environmental conditions, pollutant sources, or other factors change over time. Massachusetts Coastal Zone Management (CZM) has developed a StormSmart Coasts Program (2008) to help coastal communities address impacts and effects of erosion, storm surge and flooding which are increasing due to climate change. The program, www.mass.gov/czm/stormsmart offers technical information, planning strategies, legal and regulatory tools to communities to adapt to climate change impacts.

As more information and tools become available, there may be opportunities to make adjustments in TMDLs in the future to address predictable climate change impacts. When the science can support assumptions about the effects of climate change on the nitrogen loadings to ~~Lake Tashmoo~~Wild Harbor the TMDL can be reopened, if warranted.

The watershed community of Falmouth is urged to meet the target threshold N concentrations by reducing N loadings from any and all sources, through whatever means are available and practical, including reductions in on-site subsurface wastewater disposal system loadings as well as reductions in stormwater runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of stormwater Best Management Practices (BMPs).

MassDEP's MEP Implementation Guidance report (http://www.mass.gov/eea/docs/dep/water/resources/a-thru-m/mepmain.pdf with appendices at http://www.mass.gov/eea/docs/dep/water/resources/a-thru-m/mepappen.pdf) provides N loading reduction strategies that are available to Falmouth that could be incorporated into the implementation plans. The following topics related to N reduction are discussed in the Guidance:

- Wastewater Treatment;
    - On-Site Treatment and Disposal Systems
    - Cluster Systems with Enhanced Treatment
    - Community Treatment Plants
    - Municipal Treatment Plants and Sewers
- Tidal Flushing;
    - Channel Dredging
    - Inlet Alteration
    - Culvert Design and Improvements
- Stormwater Control and Treatment*;
    - Source Control and Pollution Prevention
    - Stormwater Treatment
- Attenuation via Wetlands and Ponds;
- Water Conservation and Water Reuse;
- Management Districts;
- Land Use Planning and Controls;
    - Smart Growth
    - Open Space Acquisition
    - Zoning and Related Tools
- Nutrient Trading.

*The towns of Falmouth, Bourne and Sandwich are members of the 237 communities in Massachusetts currently covered by the Phase II storm water program requirements.

Monitoring Plan

MassDEP is of the opinion that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. MassDEP's position is that implementation will be conducted through an iterative process where adjustments may be needed in the future. The two forms of monitoring include: 1) tracking implementation progress as approved in the town CWMP plan (as appropriate); and 2) monitoring ambient water quality conditions, including but not limited to, the sentinel station identified in the MEP Technical Report.

If necessary to achieve the TMDL, the CWMP will evaluate various options to achieve the goals set out in the TMDL and Technical Report. It will also make a final recommendation based on existing or additional modeling runs, set out required activities and identify a schedule to achieve the most cost effective solution that will result in compliance with the TMDL. Once approved by MassDEP, tracking progress on the agreed-upon plan will, in effect, also be tracking progress towards water quality improvements in conformance with the TMDL.

Relative to water quality, MassDEP believes that an ambient monitoring program, much reduced from the data collection activities needed to properly assess conditions and to populate the model, will be important to determine actual compliance with water quality standards. Although the TMDL load values are not fixed, the target threshold N concentrations at the sentinel stations are. Through discussions amongst the MEP it is generally agreed that existing monitoring programs which were designed to thoroughly assess conditions and populate water quality models can be substantially reduced for compliance monitoring purposes. Although more specific details need to be developed on a case by case basis, MassDEP's current thinking is that about half the current effort (using the same data collection procedures) would be sufficient to monitor compliance over time and to observe trends in water quality changes. In addition, the benthic habitat and communities would require periodic monitoring on a frequency of about every 3-5 years. Finally, in addition to the above, existing monitoring conducted by MassDEP for eelgrass should continue into the future to observe any changes that may occur to eelgrass populations as a result of restoration efforts.

The MEP will continue working with the watershed communities to develop and refine monitoring plans that remain consistent with the goals of the TMDL. Through the adaptive management approach ongoing monitoring will be conducted and will indicate if water quality standards are being met. If this does not occur other management activities would have to be identified and considered to reach to goals outlined in this TMDL. It must be recognized however that development and implementation of a monitoring plan will take some time, but it is more important at this point to focus efforts on reducing existing watershed loads to achieve water quality goals.

Reasonable Assurances

MassDEP possesses the statutory and regulatory authority, under the water quality standards and/or the State Clean Water Act (CWA), to implement and enforce the provisions of the TMDL through its many permitting programs, including requirements for N loading reductions from on-site subsurface wastewater disposal systems. However, because most non-point source controls are voluntary, reasonable assurance is based on the commitment of the locality involved. Falmouth has demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL as well as proceeding with construction of a larger culvert to improve flushing within the embayment. The town expects to use the information in this TMDL to generate support from their citizens to take the necessary steps to remedy existing problems related to N loading from on-site subsurface wastewater disposal systems, stormwater, and runoff (including fertilizers) and to prevent any future degradation of these valuable resources.

Moreover, reasonable assurances that the TMDL will be implemented include enforcement of regulations, availability of financial incentives and local, state and federal programs for pollution control. Stormwater NPDES permit coverage will address discharges from municipally owned stormwater drainage systems. Enforcement of regulations controlling non-point discharges include local implementation of the Commonwealth’s Wetlands Protection Act and Rivers Protection Act; Title 5 regulations for on-site subsurface wastewater disposal systems and other local regulations such as the Town of Rehoboth’s stable regulations.

Financial incentives include federal funds available under Sections 319, 604 and 104(b) programs of the CWA, which are provided as part of the Performance Partnership Agreement between MassDEP and EPA. Other potential funds and assistance are available through Massachusetts' Department of Agriculture's Enhancement Program and the United States Department of Agriculture's Natural Resources Conservation Services. Additional financial incentives include income tax credits for Title 5 upgrades and low interest loans for Title 5 on-site subsurface wastewater disposal system upgrades available through municipalities participating in this portion of the state revolving fund program.

As the town implements this TMDL, the TMDL values (kg/day of N) will be used by MassDEP as guidelines for permitting activities and should be used by local communities as a management tool.

Public Participation

Public meetings to present the results of and answer questions on this TMDL were held on XXXX in the XXXX meeting room. XXXXX (MassDEP) summarized the Mass Estuaries Project and described the Draft Nitrogen TMDL Report findings. Public comments received at the public meetings and comments received in writing within a 30-day comment period following the public meeting were considered by the Department. This final version of the TMDL report includes both a summary of the public comments together with the Department's response to the comments and scanned images of the attendance sheets from the meetings (Appendix XX). MEP representatives at the public meetings included XXXXXXX.

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Appendix A: Overview of Applicable Water Quality Standards

Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, bottom pollutants or alterations, aesthetics, excess plant biomass, and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen, but have only narrative standards that relate to the other variables. This brief summary does not supersede or replace 314 CMR 4.0 Massachusetts Water Quality Standards, the official and legal standards. A complete version of 314 CMR 4.0 Massachusetts Water Quality Standards is available online at http://www.mass.gov/eea/agencies/massdep/water/regulations/314-cmr-4-00-mass-surface-water-quality-standards.html

Applicable Narrative Standards

314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances, produce objectionable odor, color, taste, or turbidity, or produce undesirable or nuisance species of aquatic life."

314 CMR 4.05(5)(b) states "Bottom Pollutants or Alterations. All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms."

314 CMR 4.05(5)(c) states, "Nutrients –Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department pursuant to 314 CMR 4.00. Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication, including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment as determined by the Department, including, where necessary, highest and best practical treatment (HBPT) for POTWs and BAT for non POTWs, to remove such nutrients to ensure protection of existing and designated uses. Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control."

Description of Coastal and Marine Classes and Numeric Dissolved Oxygen Standards

Excerpt from 314 CMR 4.05(4) (a):

(a) Class SA. These waters are designated as an excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value.

1. Dissolved Oxygen. Shall not be less than 6.0 mg/l. Where natural background conditions are lower, DO shall not be less than natural background. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

Excerpt from 314 CMR 4.05(4) (b):

(b) Class SB. These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.

1. Dissolved Oxygen. Shall not be less than 5.0 mg/l. Seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. Where natural background conditions are lower, DO shall not be less than natural background.

Waterbodies Not Specifically Designated in 314 CMR 4.06 or the tables to 314 CMR 4.00

Note many waterbodies do not have a specific water quality designation in 314 CMR 4.06 or the tables to 314 CMR 4.00**.** Coastal and Marine Classes of water are designated as Class SA and presumed High Quality Waters as described in 314 CMR 4.06 (4).

314 CMR 4.06(4):

(4) Other Waters. Unless otherwise designated in 314 CMR 4.06 or unless otherwise listed in the tables to 314 CMR 4.00, other waters are Class B, and presumed High Quality Waters for inland waters and Class SA, and presumed High Quality Waters for coastal and marine waters. Inland fisheries designations and coastal and marine shellfishing designations for unlisted waters shall be made on a case-by-case basis as necessary.

Applicable Antidegradation Provisions

Applicable antidegradation provisions are detailed in 314 CMR 4.04 from which an excerpt is provided:

Excerpt from 314 CMR 4.04:
4.04:Antidegradation Provisions

(1) Protection of Existing Uses. In all cases existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

(2) Protection of High Quality Waters. High Quality waters are waters whose quality exceeds minimum levels necessary to support the national goal uses, low flow waters, and other waters whose character cannot be adequately described or protected by traditional criteria. These waters shall be protected and maintained for their existing level of quality unless limited degradation by a new or increased discharge is authorized by the Department pursuant to 314 CMR 4.04(5). Limited degradation also may be allowed by the Department where it determines that a new or increased discharge is insignificant because it does not have the potential to impair any existing or designated water use and does not have the potential to cause any significant lowering of water quality.

(3) Protection of Outstanding Resource Waters. Certain waters are designated for protection under this provision in 314 CMR 4.06. These waters include Class A Public Water Supplies (314 CMR 4.06(1)(d)1.) and their tributaries, certain wetlands as specified in 314 CMR 4.06(2) and other waters as determined by the Department based on their outstanding socio-economic, recreational, ecological and/or aesthetic values. The quality of these waters shall be protected and maintained.

(a) Any person having an existing discharge to these waters shall cease said discharge and connect to a Publicly Owned Treatment Works (POTW) unless it is shown by said person that such a connection is not reasonably available or feasible. Existing discharges not connected to a POTW shall be provided with the highest and best practical method of waste treatment determined by the Department as necessary to protect and maintain the outstanding resource water.

(b) A new or increased discharge to an Outstanding Resource Water is prohibited unless:

1. the discharge is determined by the Department to be for the express purpose and intent of maintaining or enhancing the resource for its designated use and an authorization is granted as provided in 314 CMR 4.04(5). The Department's determination to allow a new or increased discharge shall be made in agreement with the federal, state, local or private entity recognized by the Department as having direct control of the water resource or governing water use; or

2. the discharge is dredged or fill material for qualifying activities in limited circumstances, after an alternatives analysis which considers the Outstanding Resource Water designation and further minimization of any adverse impacts. Specifically, a discharge of dredged or fill material is allowed only to the limited extent specified in 314 CMR 9.00 and 314 CMR 4.06(1)(d). The Department retains the authority to deny discharges which meet the criteria of 314 CMR 9.00 but will result in substantial adverse impacts to the physical, chemical, or biological integrity of surface waters of the Commonwealth

(4) Protection of Special Resource Waters. Certain waters of exceptional significance, such as waters in national or state parks and wildlife refuges, may be designated by the Department in 314 CMR 4.06 as Special Resource Waters (SRWs). The quality of these waters shall be maintained and protected so that no new or increased discharge and no new or increased discharge to a tributary to a SRW that would result in lower water quality in the SRW may be allowed, except where:

(a) the discharge results in temporary and short term changes in the quality of the SRW, provided that the discharge does not permanently lower water quality or result in water quality lower than necessary to protect uses; and

(b) an authorization is granted pursuant to 314 CMR 4.04(5).

(5) Authorizations.

(a) An authorization to discharge to waters designated for protection under 314 CMR 4.04(2) may be issued by the Department where the applicant demonstrates that:

1. The discharge is necessary to accommodate important economic or social development in the area in which the waters are located;

2. No less environmentally damaging alternative site for the activity, receptor for the disposal, or method of elimination of the discharge is reasonably available or feasible;

3. To the maximum extent feasible, the discharge and activity are designed and conducted to minimize adverse impacts on water quality, including implementation of source reduction practices; and

4. The discharge will not impair existing water uses and will not result in a level of water quality less than that specified for the Class.

(b) An authorization to discharge to the narrow extent allowed in 314 CMR 4.04(3) or 314 CMR 4.04(4) may be granted by the Department where the applicant demonstrates compliance with 314 CMR 4.04(5)(a)2. through 314 CMR 4.04(5)(a)4.

(c) Where an authorization is at issue, the Department shall circulate a public notice in accordance with 314 CMR 2.06. Said notice shall state an authorization is under consideration by the Department, and indicate the Department's tentative determination. The applicant shall have the burden of justifying the authorization. Any authorization granted pursuant to 314 CMR 4.04 shall not extend beyond the expiration date of the permit.

(d) A discharge exempted from the permit requirement by 314 CMR 3.05(4) (discharge necessary to abate an imminent hazard) may be exempted from 314 CMR 4.04(5) by decision of the Department.
(e) A new or increased discharge specifically required as part of an enforcement order issued by the Department in order to improve existing water quality or prevent existing water quality from deteriorating may be exempted from 314 CMR 4.04(5) by decision of the Department.

(6) The Department applies its Antidegradation Implementation Procedures to point source discharges subject to 314 CMR 4.00.

(7) Discharge Criteria. In addition to the other provisions of 314 CMR 4.00, any authorized Discharge shall be provided with a level of treatment equal to or exceeding the requirements of the Massachusetts Surface Water Discharge Permit Program (314 CMR 3.00). Before authorizing a discharge, all appropriate public participation and intergovernmental coordination shall be conducted in accordance with Permit Procedures (314 CMR 2.00).

Appendix B: Summary of the Nitrogen Concentrations in Wild Harbor Estuarine System

Table B-1: Summary of the Nitrogen Concentrations for the Wild Harbor Estuarine System (Reprinted from Table VI-1 of the MEP Technical Report, Howes *et al*, 2013)

Measured data and modeled Nitrogen concentrations for the Wild Harbor estuarine system. All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means. Data represented in this table were collected in the summers of 1999 through 2009.

Sub-Embayment	MEP monitoring station	data mean	s.d. all data	N	model min	model max	model average
Wild Harbor (outlet of the Boat Basin)	WH-1	0.439	0.071	38	0.359	0.546	0.447
Wild Harbor River	WH-2	0.480	0.107	40	0.332	0.779	0.482
Buzzards Bay	CBB1	0.282	0.044	13	-	-	-

Appendix C: Stormwater Loading Information

Table C-1: The Wild Harbor Estuarine System estimated waste load allocation (WLA) from runoff of all impervious areas within 200 feet of its waterbodies.

Estuary System Name	Watershed Impervious Area in 200 ft Buffer of Embayment Waterbody (acres)[1]	Total Watershed Impervious Area (acres)[2]	Watershed Impervious Area in 200 ft buffer as % of Total Watershed Impervious Area	MEP Total Unattenuated Watershed Impervious Load (kg/day)[3]	MEP Total Unattenuated Watershed Load (kg/day)[4]	Watershed Impervious buffer (200 ft) WLA (kg/day)[5]	Watershed buffer area WLA as percentage of MEP Total Unattenuated Watershed Load[6]
Wild Harbor and Wild Harbor River	11.03	160	6.9%	2.08	26.61	0.14	0.5%

1. The entire impervious area within a 200 foot buffer zone around all waterbodies as calculated by MassGIS. Due to the soils and geology of Cape Cod it is unlikely that runoff would be channeled as a point source directly to a waterbody from areas more than 200 feet away. Some impervious areas within approximately 200 feet of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of the waste load allocation (WLA) it was assumed that all impervious surfaces within 200 feet of the shoreline discharge directly to the waterbody.

2. Total impervious surface for the watershed was obtained from SMAST N load data files.

3. From Table IV-3 of the MEP Technical Report.

4. This includes the unattenuated nitrogen loads from wastewater from septic systems, fertilizer, runoff from both natural and impervious surfaces, and atmospheric deposition to freshwater waterbodies. This does not include direct atmospheric deposition to the estuary surface.

5. The impervious subwatershed 200 ft buffer area (acres) divided by total watershed impervious area (acres) then multiplied by total impervious subwatershed load (kg/day).

6. The impervious subwatershed buffer area WLA (kg/day) divided by the total subwatershed load (kg/day) then multiplied by 100.

Appendix D: Wild Harbor Total Nitrogen TMDLs

Table D-1: TMDLs for Wild Harbor Estuarine System – One Total Nitrogen TMDLs and Two Protective TMDLs

Waterbody Name	Segment ID	Segment Description	TMDL Type	TMDL (kg N/day)
Wild Harbor	MA95-20	Falmouth	Restoration	**5.58**
Wild Harbor River	MA95-68	Headwaters, Falmouth to mouth at Wild Harbor, Falmouth.	Protective*	10.51
Dam Pond Stream	not assigned	Outlet of Dam Pond	Protective	1.51
Wild Harbor (total system)				17.6

* Wild Harbor River was not found impaired by the MEP project, however, the restoration of Wild Harbor will require reductions in loadings to the Wild Harbor River watershed.